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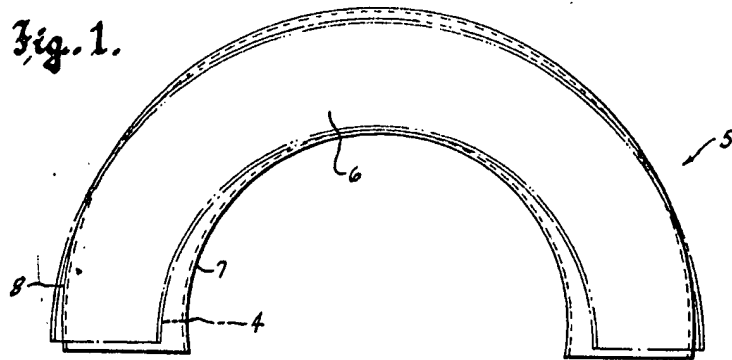


Fig. 2.

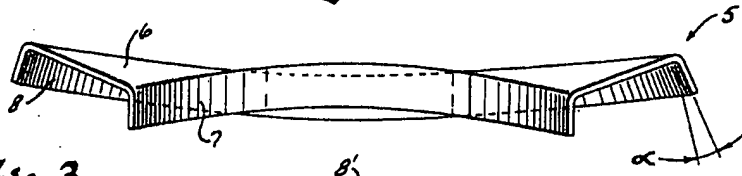


Fig. 3.

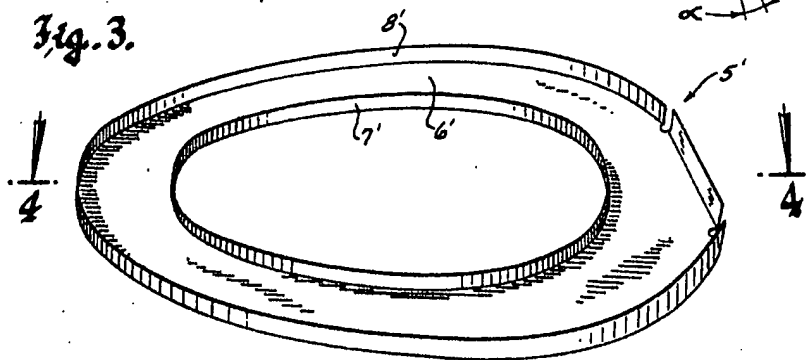
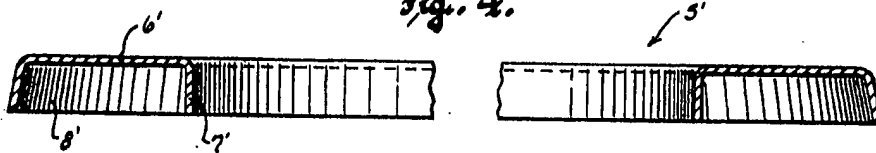


Fig. 4.



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Fig. 5.

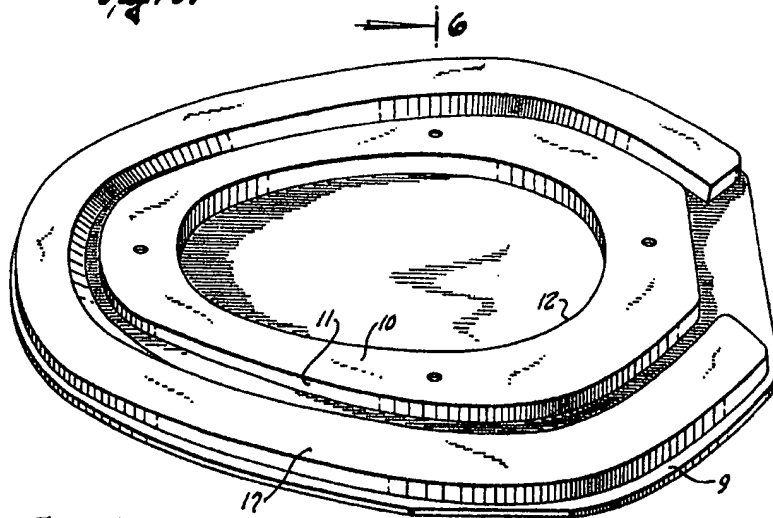
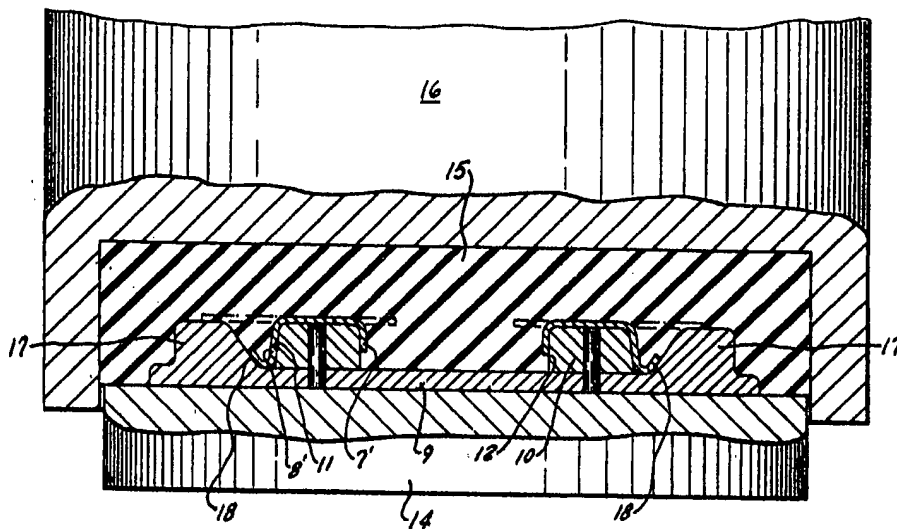
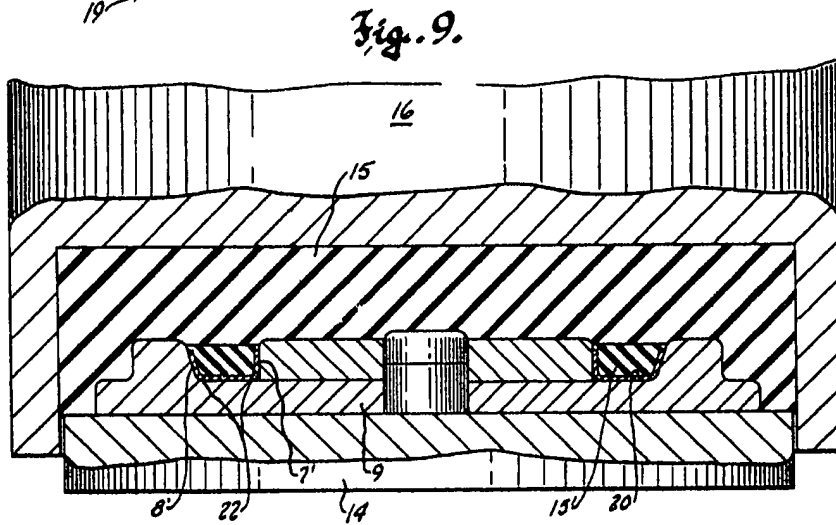
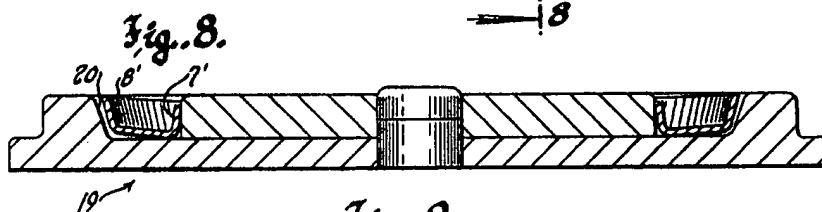
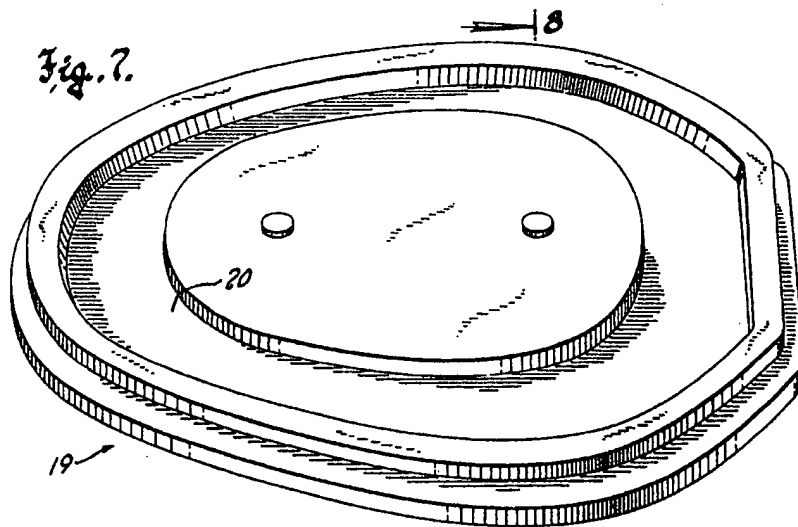


Fig. 6.



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This invention relates to the bending of sheet metal articles having compound curvatures, and refers more particularly to a method of bending, from a unitary, substantially flat sheet metal blank, an article having a portion curved along mutually perpendicular radii.

In forming blanks of sheet metal having a high elastic limit into articles having compound curves, it has heretofore been necessary to provide some compensation in the forming die for the spring-back which is inevitable in working with such metal. Since it has not heretofore been feasible to produce forming dies which provided complete compensation for spring-back in parts with relatively complex shapes, the customary practice has been to employ a die which produced as nearly as possible a part having the desired form, and then to rework the part to bring it into conformity with the desired shape.

The reworking was usually done after the part had been heat treated, using a template or templates to insure that the required form was obtained. The necessity for such reworking was in itself burdensome, but a more serious disadvantage of the previous practice arose from the fact that the reworking imposed internal stresses upon the metal. In the case, for example, of an aircraft part, such as a portion of a fuselage shell, the formed metal was frequently drilled at several points after it had been finally worked to the desired shape, and the boring or punching of holes therein released the internal stresses which had been introduced by the

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reworking operation, with the result that the part would spring slightly out of its desired form and, therefore, would not mate up or align properly with other parts of the assembly.

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With the foregoing disadvantages of the prior practice in mind, it is an object of the present invention to provide a method of forming sheet metal articles having compound curves, whereby the final forming operation upon the article may be accomplished with the use of a die having a shape which accurately conforms to that of the desired part, thus obviating the necessity for special reworking of the part to bring it to the required shape.

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Another object of this invention resides in the provision of a method of shaping sheet metal articles having compound curves, which method essentially entails two forming operations, the second of which creates internal stresses in the metal of the article which substantially offset those created therein by the first, so that the finished product has a stable form that is not affected by the drilling or punching of holes therein or by other operations which may locally relieve internal stresses.

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A further object of this invention resides in the provision of a method for bending, from unitary, substantially flat sheet metal blanks, articles having compound curves, which method may be practiced by the use of a forming die and a co-operating body of rubber or similar resilient

material, used in a press, and which method permits accurate predetermination of the configuration of the required finish forming die to produce a desired shape without the necessity for extensive experiment.

Still another object of this invention resides in the provision of a method of forming sheet metal articles having compound curves, such as an article having an integral flange extending along a curved edge thereof, wherein smaller bending radii can be obtained in the finished article than has heretofore been possible.

With the above and other objects in view which will appear as the description proceeds, this invention resides in the novel method and process substantially as hereinafter described and more particularly defined by the appended claims, it being understood that such changes in the precise embodiment of the hereindisclosed invention may be made as come within the scope of the claims.

The accompanying drawings illustrate one complete example of the physical embodiment of the practice of the method of this invention according to the best mode so far devised for the practical application of the principles thereof, and in which:

Figure 1 is a top plan view of an article of a type which may be produced by the method of this invention, but which was produced in accordance with the prior practice, the article being shown before reworking thereof;

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Figure 2 is a front view of the article shown in Figure 1;

4 Figure 3 is a perspective view of an article produced by the method of this invention, the article being shown in finished form;

Figure 4 is a sectional view taken on the plane of the line 4-4 in Figure 3;

8 Figure 5 is a perspective view of a die or forming block employed in the first step of producing the article shown in Figures 3 and 4 according to the method of this invention;

12 Figure 6 is a sectional view taken on the plane of the line 6-6 in Figure 5 but showing the die in use in a forming press;

16 Figure 7 is a perspective view of a die or forming block by which the second step in the forming of the article shown in Figure 3 may be performed;

20 Figure 8 is a sectional view taken on the plane of the line 8-8 in Figure 7, but with the partially formed article in place in the die; and

24 Figure 9 is a sectional view similar to Figure 6 but showing the die block of Figure 7 in use in a forming press.

Referring now to the accompanying drawings in which like numerals designate like parts throughout the several views, the numeral 5 designates

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generally an article formed from a unitary sheet of metal, such as aluminum, and having an arcuate body portion 6 with an inner flange 7 and an outer flange 8 extending along its arcuate edges. (See Figure 1.)

If the part 5 has been bent according to prior practice by means of a die block (not shown) which gives it the contour indicated by the broken line 4 so long as forming pressure is applied to the part while in the die block, the article will at once assume the configuration indicated by solid lines when it is removed from the die, due to the spring-back inherent in metal having a high elastic limit. In the initial bending operation the material forming the inner flange 7 is expanded, while that which forms the outer flange 8 is compressed, and consequently the spring-back also causes the body portion 6 of the article to be sprung or warped out of flatness, as shown in Figure 2. Moreover, the flange angle departs from that provided by the forming block, as indicated by the angle .

The extent of the departure from the desired form depends upon the geometry of the particular part or article, the thickness of the sheet metal material, the condition of the material (as, for example, whether it is annealed, heat-treated but unaged, or heat-treated and aged), and the forming practice employed. Because of these several variables, the spring-back in any given portion of the formed article can only be determined empirically, and full compensation for spring-back in the forming block or die has not heretofore been practicable. It has

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been the practice, heretofore, to rework the part after heat treatment, because heat treatment introduces further discrepancies into its shape or form, so that if the article were heat treated after being reworked, further reworking would usually be required.

The present invention contemplates that the article will be initially bent from a flat blank, and that a predetermined departure from the desired form will be incorporated into the shape of the article; and then, preferably after heat treatment, the article will be rebent to impart the final desired shape thereto, such rebending being done along a bending zone displaced from that of the initial bend and substantially parallel thereto, and being accomplished by means of a die or forming block which exactly corresponds in shape to the desired final shape of the article, without any compensation for spring-back.

The method is hereinafter more particularly illustrated and described with reference to the forming of an airplane fuselage member 5' (see Figure 3 and 4) having a flat, substantially annular body portion 6', an inner flange 7' bent on a small radius and extending around the inner periphery of the body portion and disposed substantially normal thereto, and a similar outer flange 8' extending around the outer periphery of the body portion. The blank (not shown) from which the article is formed is, of course, annular and has an outline roughly similar to the

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shape of the finished article, as will be well understood by those skilled in the art.

The first bending or forming operation is preferably accomplished with the blank in annealed condition, employing a die having a base 9 (see Figure 5) and an annular forming body 10 projecting up from the base and the shape of which corresponds approximately to that of the desired article, but which varies therefrom in predetermined respects, and specifically, in that the forming body 10 of the die is narrower than the body portion 6' of the desired article. Thus the outer periphery 11 of the annular forming body of the die will have a slightly smaller radius than the radius along which the outer flange 8' extends on the finished article, while the inner periphery 12 of the annular forming body will have a larger radius than that along which the inner flange 7' of the article is bent. Stated another way, the forming die is so constructed that in the first bending operation the flanges will be bent along curved zones which are displaced radially, in directions away from the curved edges of the blank, from the zones along which the flanges of the article will be bent in its finished form. The amount of this radial displacement of the bending zones in the initial bending operation is preferably substantially equal to the thickness of the metal of the blank.

The die block is used in a conventional forming press, being placed on the lower jaw 14 thereof (see Figure 6), and, by means of a rubber or

other resilient forming member 15 held by the upper jaw 16 of the press, the sheet metal blank is bent around the forming body portion 10 of the die block.

4 A supporting wall 17 on the die block, surrounding the forming body portion and having an obliquely disposed surface, prevents wrinkling of the outer flange 8' as compressive forming force is applied to  
8 the outer marginal edge portion of the blank to form the same.

After the part is thus preliminarily bent to shape, the burr 18 is removed and the part  
12 is preferably solution heat treated. Next the partially finished article is placed in a finish forming die 19 (see Figure 7 and 8) having a cavity 20 therein which corresponds in shape to  
16 the desired form of the finished article. When inserted into the cavity in this die, the partially finished article will, of course, fit it somewhat loosely because of the fact that its body portion  
20 6' was deliberately made too narrow, and in addition it will, of course, be substantially warped and twisted due to spring-back from the previous bending operation and the relief of internal stresses during  
24 heat treatment.

The finish die 19 is also used with a forming press and a cooperating resilient forming member 15', and during the second bending operation  
28 the bending zones 22 are, of course, displaced radially toward the free edges of the blank. In consequence of such displacement of the bending zones, internal tension stresses are set up in the outer flange and

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4 internal compression stresses are created in the inner  
flange, and these new stresses, being opposite to the  
internal stresses set up in the metal by the first bend-  
ing operation, substantially offset them. As a result, the  
article comes out of the second bending operation with a  
true form, having its body portion flat and its shape  
accurately corresponding to that of the finish forming  
8 die.

In general, therefore, the method of  
this invention may be said to comprise two bending  
steps, in the first of which the blank is bent  
12 along a curved zone or zones displaced from the zone  
of curvature desired in the finished article and  
substantially parallel thereto, and in the second of  
which (performed after heat treatment) the blank is  
16 rebent along a zone corresponding exactly to the  
bending zone desired in the finished article and to  
the exact finished form desired. The important  
feature of these two bending operations is the  
20 displacement of the curved bending zone radially  
in a direction to impose upon the article internal  
stresses, created by the second bending operation,  
which substantially offset or counteract those  
24 created by the first bending operation so that the  
finished article will have no spring-back.

The performance of the second  
bending operation after heat treatment assures that  
28 the part will have a comparatively small remainder  
of equally distributed stresses, which will not be  
released by the formation of holes, or other local  
operations; and this follows from the fact that the

4 strains involved in the second bending step after heat treatment, and the related spring-back, are of about the same magnitude as the strains and related spring-back involved in the first bending step performed upon the blank in annealed condition.

8 Because the bending zone is displaced parallel to itself, a flange formed by the method of this invention will have no spring-back in relation to the finish forming die block, and no compensation for spring-back need be made in the provision of the flange angle forming elements of  
12 the finish forming die.

16 From the foregoing description taken together with the accompanying drawings it will be apparent that this invention provides a method of forming, from sheet metal blanks, articles having compound curves, whereby the final form of the articles may be imparted thereto by means of a finish forming die having a shape  
20 exactly corresponding to that of the desired finished article (no compensation for spring-back being necessary) and whereby a finished article is produced which is stable in that it will accurately  
24 hold its shape even when holes are made therein or other local operations are performed thereon by which internal stresses might be released.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. The method of forming a substantially flat blank of metal into an article having a substantially planar body portion and having an integral flange connected with the body portion by an integral zone of the article having a compound curve, which method is characterized by the steps of: applying substantially evenly distributed forming forces to the blank in directions which are at all times and in all places on the blank substantially normal to the surfaces thereof, by which forces the metal of a marginal edge portion of the blank is compelled to undergo a displacement which produces a bend along a curved zone radially spaced inwardly with respect to the body portion from the zone of compound curve between the flanges and the body portion in the finished article, to form the marginal edge portion of the blank into a flange, the even distribution of forming forces insuring that the flange will be unwrinkled and will have substantially evenly distributed internal stresses in one direction therein; and thereafter holding the body portion of the blank against displacement while applying to the flange substantially evenly distributed reforming forces which are substantially normal to the surfaces of the flange along the entire length thereof, and in a direction outwardly with respect to the body portion, to cause the flange to be translatingly displaced in a direction away from the body portion and to generate in the flange evenly distributed internal stresses in the opposite direction, whereby the effect of said first named stresses are substantially cancelled, so that the bend between the flange and the body portion of the article is caused to lie along said desired zone of compound curve.

2. The method of forming a substantially flat blank of metal into an article having a substantially planar body portion connected with an integral flange along a zone of compound curve, which method is characterized by the steps of: flatwise supporting one surface of the blank by means of a rigid forming member which engages the body portion of the blank and leaves unsupported a curved marginal portion of the blank, the inner edge of which marginal portion is radially spaced inwardly with respect to the body portion from the desired zone of compound curve in the finished article; simultaneously compressing a yielding forming member against the other surface of the blank, over the entire unsupported marginal portion thereof and over a substantial part of the supported area adjacent thereto, to apply to the blank an evenly distributed forming force which is at all times substantially normal to the surfaces thereof, thereby producing in the blank a bend along a zone of compound curve radially spaced inwardly with respect to the body portion from the desired zone of compound curve connecting the flange with the body portion in the finished article and forming the unsupported marginal portion of the blank into an unwrinkled flange having substantially evenly distributed internal stresses in one direction therein; and thereafter compressing a resilient forming member against substantially all of that surface of the flange which faces the body portion of the blank, while confining the body portion of the blank against displacement, to apply to the flange substantially evenly distributed reforming pressure by which the flange is translatingly displaced in a direction away from the body portion, to cause the bend between the flange and the body portion of the article to be moved to said desired zone of compound curve connecting the flange with the body portion, and to generate in the flange uniformly distributed internal stresses in the opposite direction whereby the effects of said first named forces are substantially cancelled.

3. The method of cancelling the effect of distorting stresses from a sheet metal article of the type having a substantially planar body portion and an inwrinkled lengthwise curved flange integral with said body portion, which article is warpedly distorted from its desired form by reason of stresses in its flange acting in directions lengthwise thereof and generated in the initial formation of the flange, which method comprises: holding the body portion of the article against displacement while applying to the flange forces distributed substantially evenly over its entire surface to translatingly displace the entire flange through a distance such that new internal stresses are created in the flange which are substantially equal in magnitude to those originally present therein, said translation being in a direction away from the body portion so that said new internal stresses are opposite in direction to those originally present in the flange and so that the effects of the stresses in the article substantially cancel one another present in the flange.